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Reclamation and Reuse of Fruit Processing Wastewater

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RECLAMATION AND REUSE OF FRUIT PROCESSING WASTEWATER

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SUMMARY: It is technically and economically feasible to renovate and reuse fruit cannery wastewater as a process water supply without adversely affecting product safety or quality. However, the chemical, physical and bacteriological quality of the renovated wastewater, along with consistency of quality, are critical in determining where this water can be reused within the processing facility. The wastewater reclaimed under this study contained no sanitary wastes. Study results indicate that it is feasible, at the test site, to reduce wastewater discharge and fresh water demand by over 50%.

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RECLAMATION AND REUSE OF FRUIT PROCESSING WASTEWATER

by

H. W. Thompson* and L. A. Esvelt, Ph. D.**

INTRODUCTION

Background

Since 1974 Snokist Growers Inc. has conducted, under EPA Grant No. S-803280, a study designed to evaluate the techno-economic feasibility of reusing treated process wastewater. This study was conducted at the Growers' Yakima, WA, cannery with data collected throughout the 1975 and 1976 processing campaigns.

Snokist processes peaches, pears, apples, crabapples, plums and cherries. Their major pack consists of peaches, pears and apples with the processing of these commodities occurring between the middle of August and the middle of January. Final product styles are peach and pear slices and halves, and apple slices and sauce. Processing capacity is about 300 metric tons (kkg) per day for peaches and pears, and 100 tons per day for apples.

Snokist's process wastewater treatment facilities were installed in 1968 and are described in detail in an EPA R,D&D report[1]. Their treatment system was designed for a BOD_5 loading of 7.3 kkg/day and a flow of 6800 m^3/day. This system consists of screening, nutrient addition (N & P), biological treatment (activated sludge), sludge reaeration, and sludge thickening. Snokist's process wastewater does not contain sanitary wastes.

In 1975 multimedia pressure filters (2) and chlorination facilities were constructed to allow for a portion of the biologically treated effluent to be renovated for reuse evaluation. Facilities for the addition of chemicals were also provided. A detailed description of this renovation system will be included in the final project report[2]. Figure 1 is a schematic diagram of Snokist's treatment facilities including the reclamation facilities.

Construction cost for the 1900 m^3/day (0.5 MGD) reclamation facilities, including an in-plant distribution system, was approximately $325,000. This expenditure increased Snokist's total investment in process wastewater treatment, renovation, and handling facilities to approximately $850,000.

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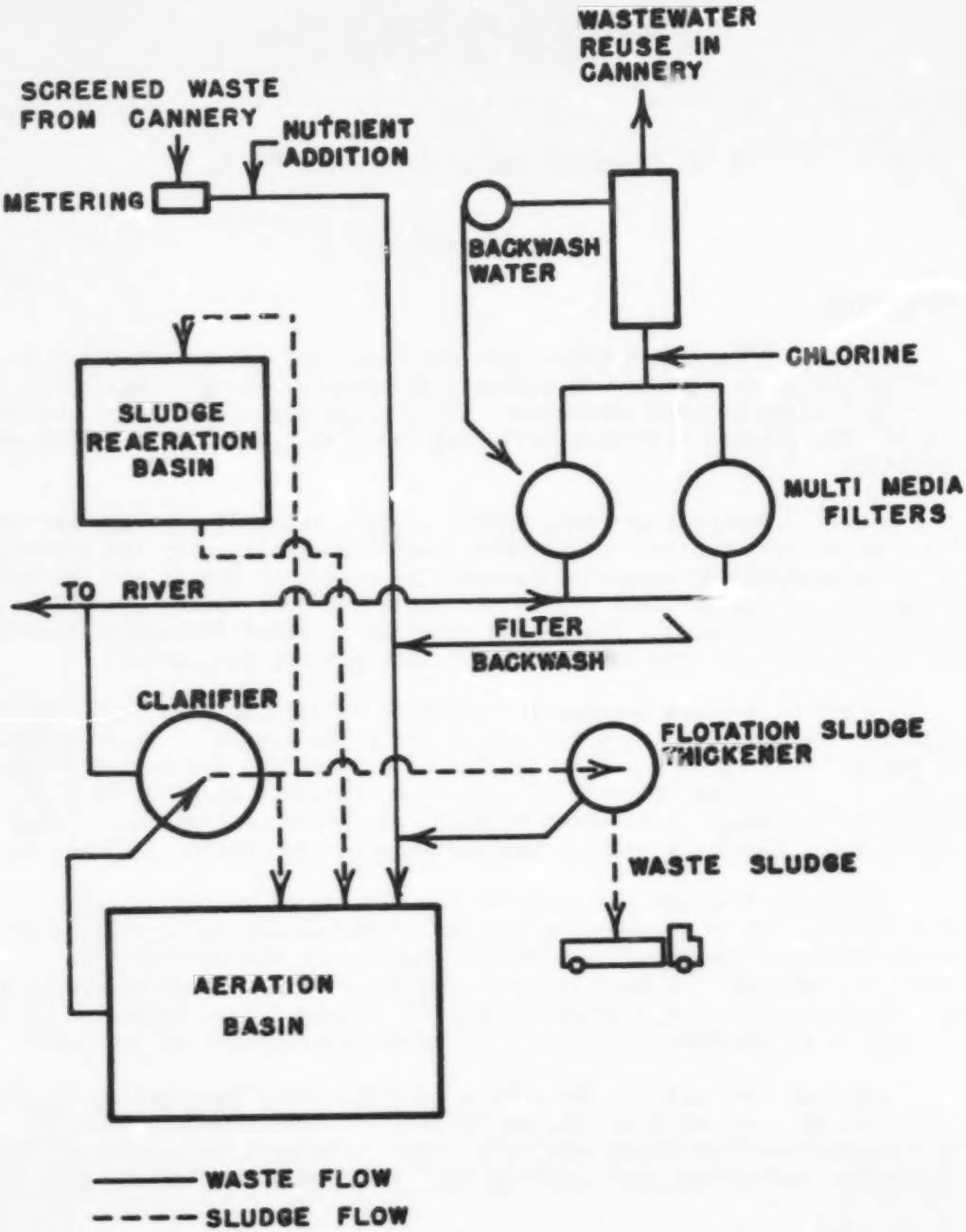

Figure 1. Schematic flow diagram of Snokist Growers' wastewater treatment system.

EPA's sponsorship of this study was part of the agencies' legislated program for assisting industry in the development of methods for reclaiming and recycling water, and confining pollutants so they will not migrate to cause water or other environmental pollution[3]. Thus, the purpose of this project from the view of EPA was one of simply responding to a legislated mandate; whereas, Snokist saw the project as a means to supplement their process water supply while simultaneously reducing their discharge of pollutants.

Project Objectives and Their Development

Two literature reviews were conducted during the formative stages of this project. One dealt with the federal regulations that govern the quality of water used in the processing of foods for human consumption. The second was a search on the subject of reclaiming terminally treated wastewater for direct contact reuse in the processing of human food products.

Through the review of federal regulations it was learned that the FDA had promulgated, under the authority provided by the Federal Food, Drug, and Cosmetic (FD&C) Act[4], a number of regulations that specify food process water quality requirements[5, 6, 7, 8, 9]. USDA, under The Poultry Products Inspection Act[10], and The Federal Meat Inspection Act[11] had also set process water requirements under their mandatory meat and poultry inspection regulations[12, 13]. Additional process water quality regulations had been promulgated by USDA as part of their continuous inspection and certification program for processed fruits, vegetables and related products[14]. These regulations were issued under The Agricultural Marketing Act[15].

Of these regulations only FDA's "Umbrella GMP's"[5] and those related to USDA's certification program[14] were pertinent to the proposed reclamation and reuse of wastewater at Snokist. Pertinence was based on Snokist thermally processing high-acid foods packaged in hermetically sealed containers, and their contracting for continuous USDA product grading. Specific references to water within these two sets of regulations are as follows:

FDA's "Umbrella GMP's"

> "Water supply. The water supply shall be sufficient for the operations intended and shall be derived from an adequate source. Any water that contacts foods or food-contact surfaces shall be safe and of adequate sanitary quality. . ."
>
> "Water used for washing, rinsing, or conveying of food products shall be of adequate quality, and water shall not be reused for washing, rinsing, or conveying products in a manner that may result in contamination of food products."
> (Note: Definition of adequate is. . ."means that which is needed to accomplish the intended purpose in keeping with good public health practice.")

USDA's Continuous Inspection Program

> ". . .water shall be of safe and sanitary quality with adequate facilities for its. . .protection against contamination and pollution."*

Based on the review of these regulations it was concluded that they did not exclude the reclamation/reuse of fruit processing wastewaters. At the same time, however, it was understood that one objective of the FD&C Act was to prohibit the introduction of adulterated food into interstate commerce, and that this act states that a food shall be deamed adulterated if it consists of any filthy, putrid, or decomposed substance; or if it has been packed under insanitary conditions whereby it may have become contaminated with filth, or whereby it may have been rendered injurious to health. Thus, it was apparent that any project involving the reuse of renovated wastewater in the processing of a food product must address product safety and quality, plant sanitation, renovated water quality, and system reliability.

The literature search revealed only two studies concerned with the direct contact reuse of terminally treated food processing wastewater. One study conducted under an EPA grant dealt with the assessment of treating poultry processing wastewater to a level suitable for reuse[16]. In this study Clise concluded that it is economically feasible to treat this wastewater to a level in compliance with the biological, chemical, and physical limits of the U.S. Drinking Water Standards. In subsequent attempts at reusing this renovated wastewater, however, Clise has found an impasse due to a USDA's regulation which requires the use of potable water within poultry processing establishments and EPA's definition of potable water[17].

The second study involved the in-plant reuse of reclaimed potato processing wastewater[18]. Lash reported that the renovated wastewater was used on the peel scrubbers and washers, and for fluming trim table wastes. No data were presented on the physical, chemical, or microbiological quality of the reclaimed water, although Lash did state that BOD_5 and SS were essentially eliminated from the wastewater and that proper chlorination effectively controlled or eliminated salmonella, staphylococcus and E. coli. Economic feasibility was reported as being positive.

Based on the reviews of the literature and federal regulations, the overall objective of the Snokist project was to evaluate the technoeconomic feasibility of renovating fruit canning wastewater for reuse as a finished process water supply. Reuse feasibility would be tested in: cleaning process equipment, conveying raw product, cooling product containers following retorting, and boiler feed. Steam generated from the reclaimed wastewater would be evaluated for use in equipment cleaning, exhausting, and product cooking and blanching.

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*Subsequent to 1974 this section has been deleted and replaced by. . ."The plant survey and inspection will be based on the regulations issued under the Federal Food, Drug, and Cosmetic Act--Human Foods; Good Manufacturing Practice (Sanitation) in Manufacture, Processing, Packing, or Holding (21 CFR, Part 128). . ."

To add credibility to this study and to address federal process regulations it was decided to include other federal agencies and industrial representatives in the development of Snokist's work plan, and to have them assist in project direction and review. Thus, at the very beginning of the project an ad hoc Process Water Reuse Advisory Committee was established. Organizations represented on this committee were: FDA Food Technology Division, USDA Food Safety and Quality Service, EPA Health Effects Research Laboratory, EPA Industrial Environmental Research Laboratory, National Food Processors Association (NFPA) Western Research Laboratory, Snokist Growers, and Snokist's consultant, Esvelt Environmental Engineering. This committee was extremely beneficial throughout this milestone project.

EVALUATION PLAN

Reuse studies were conducted using renovated effluent from Snokist's biological treatment system and their commercial processing equipment. The primary items used to assess reuse feasibility were food safety and quality, plant sanitation, and renovated water quality and variability. The reclaimed water was used during the 1975 and 1976 processing seasons in the test reuse areas. During the 1975 season uses were limited to equipment washing and cleaning, and direct contact container cooling. During the 1976 processing season, the uses were expanded to initial product conveying and cleaning, and for steam generation for various uses.

The following work plan is presented by reuse test areas with two exceptions. These exceptions are the assessment of the quality of the renovated wastewater and its variability.

Renovated Water Quality

During the 1975 and 1976 processing seasons the wastewater was monitored following filtration and following disinfection, as well as prior to filtration. The routine monitoring program is presented in Table 1.

The reclaimed effluent was also analyzed for trace material on an average of four times during each processing campaign. Analyses included reactive silicate, detergent (MBAS), polychlorinated biphenyls (PCB), volatile halogenated organics, pesticides, and the heavy metals (arsenic, lead, zinc, tin, copper, cadmium, mercury, iron, sodium, potassium, manganese, and aluminum). For comparison, heavy metal analyses were also performed on wastewater samples following the screening operation during the 76 season. (Note: analyses conducted for comparison purposes were on samples collected concurrently.)

In addition to the routine bacteriological monitoring (see Table 1) the reclaimed effluent was analyzed periodically for yeast, mold and total spore forming plate counts.

Snokist Growers' process water, which is unchlorinated well water, was sampled concurrently with the trace material reclaimed effluent sampling program. Well water samples were analyzed for the same trace contaminants; however, these samples were also analyzed for COD, total solids, ammonia, organic and nitrate nitrogen, ortho and total phosphorus, calcium, magnesium, alkalinity, chloride, sulfate and color. All tests on the well water were conducted to allow comparisons of quality to be made between the renovated water and Snokist's normal process water supply.

TABLE 1. RENOVATED WATER TESTING AND MONITORING SCHEDULE

Test	Clarifier Effluent[1]	Reclaimed Effluent Following Filters	Reclaimed Effluent Following Contact Tank
Flow Rate or Quantity		D[2]	D
Temperature, pH	D.G.[3]	D.G.	D.G.
Settleable Solids	D.G.		D.G.
Suspended & Volatile Susp. Solids	D.C.	D.C.	D.C.
Dissolved Oxygen	D.G.		D.G.
Total & Total Volatile Solids	W.C.	W.C.	W.C.
Chemical Oxygen Demand (COD)	D.C.	D.C.	D.C.
Biochemical Oxygen Demand (BOD_5)	W.C.	W.C.	
Ammonia & Organic Nitrogen (NH_3-N, Org. N)	W.C.	W.C.	
Nitrate Nitrogen (NO_3-N)	W.C.	W.C.	
Total & Orthophosphate Phosphorus (Tot P, PO_4-P)	W.C.	W.C.	
Calcium (Ca), Magnesium (Mg), Bicarbonate (HCO_3), Sulfate (SO_4), & Chloride (Cl-)	W.C.	W.C.	W.C.
Turbidity	D.G.	D.G. & Cont.	D.G.
Color			W.G.
Chlorine Residual		D.G. & Cont.[4]	D.G. & Cont.
Bacteriological			
Total Plate Count	D.G.	D.G.	D.G.
Total Coliform	D.G.	D.G.	D.G.
Fecal Coliform	W.G.	W.G.	W.G.
Staphyloccus	W.G.	W.G.	W.G.
Salmonella	W.G.	W.G.	W.G.

1. Feed water for renovation system.
2. Frequency of Monitoring: D = Each Processing Day; W = Weekly; Cont. = Continuous Recorder.
3. Type of Sample: G = Grab Sample; C = Composite Sample; Cont. = Automatic
4. Following Chlorination but ahead of contact tank.

Effluent variability was checked on 4 days during each processing campaign. On these days five grab samples were collected over an 8 hour shift of both the filtered and filtered-chlorinated effluents. Suspended solids and turbidity analyses were conducted on each sample of the chlorinated effluent. Total plate counts were conducted on all samples. On 2 of the sampling days *E. coli* analyses were conducted on all effluent samples.

The Snokist final report[2] will contain the analytical procedures and sample preservation techniques used throughout this study.

Reuse Testing

Equipment Cleaning--

The processing equipment in the cannery is normally cleaned with high pressure, chlorinated water mixed with steam from the plant boiler. Comparative cleaning studies were conducted during both the 1975 and 1976 processing seasons. These studies were in general conducted on peeled product belt conveyors (hereafter referred to as "lines"), and were conducted at the end of a processing day. For these studies the lines were either washed with reclaimed water and house steam or the normal steam-water mixture. After washdown the sanitary condition of the lines was checked. The results were used on a comparative basis, i.e., house water vs. reclaimed water.

Sanitary condition was assessed based on total plate and mold counts. These samples were collected using the swab contact method.

To insure food safety all lines cleaned with reclaimed water received an additional cleaning using the house steam-water mixture after the microbiological sampling. To maintain test uniformity the control line also received a second cleaning.

Parallel pear processing lines were evaluated several days during the 1975 season. An apple line was also used during this season. However, since the cannery has only one apple line, the test was set up to wash the line for a few days using reclaimed water and house steam, followed by a like number of days using the normal cleaning mixture.

In 1976 only the two parallel pear lines were used for equipment cleaning comparisons. The equipment was sampled and tested for sanitary condition as in 1975. Tests were conducted once each week for six weeks. The processing equipment on the line washed with renovated wastewater was rewashed as previously mentioned to assist in the prevention of food contamination.

In addition, continuous use of reclaimed water for equipment cleaning was evaluated by monitoring the microbiological quality of two parallel pear peel (waste material) slides. One cleaned with reclaimed water and house steam, the other with the normal house steam-water mixture. The purpose of this test was to determine if sanitation problems developed after prolonged use of reclaimed water. These slides were washed daily with their respective water/steam supplies for 6 weeks. Neither slide was rewashed since food safety was not an issue. The sanitary quality of the slides was determined twice weekly. Samples were collected and analyzed as for the process line cleaning experiments.

Product Cleaning and Conveying--

During the 1976 peach processing season reclaimed water was used as cushion water in the bin dump tank. Three days of testing with reclaimed water was followed by 3 days using well water. Microbiological tests were used to develop comparative data. Tests were conducted on the water in the dump tank and the peaches prior to dumping, following removal from the dump tank and following a water spray rinse derived from the same source as the water being used in the dump tank. Samples were collected twice daily, in triplicate, at each of these sites throughout the 6 day program. All samples were analyzed for total plate counts. Mesophilic spore counts were conducted on the samples collected following the spray rinse.

Peaches were selected as the initial fruit to be cleaned and conveyed in renovated wastewater. This selection was based on food safety considerations. It was felt that the sanitary quality of this fruit would be assured due to the subsequent harsh chemical treatment the fruit receives during caustic peeling.

Following analysis of the results of the peach experiments and review by the advisory committee, similar dumping comparisons for apples were conducted during the remainder of 1976. Sampling stations were the same as for peaches with samples collected on a daily basis. Two samples were collected per day of the dump tank water; all other stations were sampled once per day. All samples were collected in triplicate. Total plate counts were made on all samples. Testing of apples lasted 5 weeks, 2 weeks using reclaimed water and 3 weeks using house water.

Direct Contact Container Cooling--

During 1975 slightly over 1000 cans were cooled in the renovated wastewater; for comparative purposes an additional 1000 cans were cooled under similar conditions with house water. All test cans were cooled in the commercial coolers that had been brought up to a normal cooling temperature by steam injection (approximately 35°C). Following cooling the majority of the cans were stored in the cannery warehouse at ambient temperature, approximately 18°C. These were visually inspected for failure after 12 months of storage. One hundred containers from each treatment were shipped to NFPA's Berkeley laboratory to allow for high temperature storage. Following 3 months of storage at 30°C to simulate long-term storage, all 200 cans were inspected for swells, leakers, vacuum, spotting, and corrosion, and the product contained therein was inspected for pH, color and texture.

Approximately 3000 cans were cooled during the 1976 campaign in the commercial coolers under continuous flow conditions with each of the two water supplies. All cans were handled and inspected as in '75 except that the 200 samples shipped to NFPA were stored for 6 months at 35°C.

Throughout the '75 and '76 cooling studies the cooling water was chlorinated and a chlorine residual was maintained in the water at the point of discharge from the cooler. To prevent the sale of any inadvertently contaminated product, all cans and fruit cooled in the reclaimed water were destroyed following inspection.

Boiler Feed--

A portable steam generator was rented and installed in the cannery to convert reclaimed process wastewater to steam for various pilot uses. Pilot tests were conducted during 2 months of the 1976 processing season. The

reclaimed water steam was tested for use in cleaning equipment, exhausting, blanching and cooking.

Equipment Cleaning (Steam)--This testing program was almost identical to that presented above for "Equipment Cleaning," the only differences being that these tests were conducted only during the 1976 campaign, and only the pear processing lines were used to gather comparative data.

All monitoring was conducted simultaneously with the 6 weeks of monitoring of the parallel pear processing lines (see Equipment Cleaning subsection). Thus, 6 weeks of comparative microbiological data were collected from three parallel processing lines with each line being used to assess a different cleaning treatment. One line was used as a control, it was cleaned with house water and steam. The other lines were: (a) cleaned with reclaimed water and house steam, and (b) cleaned with reclaimed water and reclaimed water steam.

The long term effect of cleaning with reclaimed water and reclaimed water steam was also evaluated by monitoring a peel slide on the third pear line. The details of this evaluation were identical to, and conducted with, the long term water reuse cleaning experiments (see Equipment Cleaning subsection).

Exhausting--Many fruits and vegetables which are preserved by thermal processing and stored in sealed cans are "exhausted" before the can lid is seamed into place. This consists of passing the filled can through an "exhaust box" where live steam is applied which exhausts all of the air from the head space and preheats the can contents before the can lid is applied. During two short pilot runs steam from the portable steam generator, using reclaimed water, was used to exhaust a batch of canned pears to compare with pears exhausted using the house steam under normal continuous processing procedures. Evaluations were made by grading the processed fruit and by organoleptic evaluation. The organoleptic evaluation was conducted according to the "triangle test" (for procedure see reference No. 2).

Cooking--Steam generated from the portable boiler was used to batch cook applesauce during two pilot runs during the 1976 processing season. The commercial applesauce cooker operates on a continuous basis with a scroll auger to move the applesauce through in a certain time period. However, during experimental testing it was necessary to operate this cooker in a batch mode. The experiment consisted of batch cooking applesauce with steam generated from reclaimed water. This applesauce was then canned. A similar batch was cooked with steam generated from house water and canned for comparison.

Batch cooking consisted of filling the cooker with applesauce and injecting steam to bring the applesauce up to the specified cooking temperature and holding it at this temperature for the required period.

Near the end of the processing day containers of applesauce continuously cooked prior to the batch testing were also retained for comparison with the batch cooked applesauce. Thus, three sets of samples from each of the two runs were retained for testing by USDA grading procedures and by organoleptic evaluations.

Blanching--During the 1976 season, apple slices were blanched using reclaimed water steam from the portable steam generator. Two separate runs of blanching with the reclaimed water steam and with house steam were conducted for comparison. The normal blanching operation, as with the applesauce cooking, is continuous. For experimental purposes batch processing was required. During test blanching, the blancher was filled with apple slices and then reclaimed water steam was injected to bring it up to blanching temperature. The apple slices were canned for preservation. A similar batch of apple slices was blanched under the same conditions with steam generated from house water for comparison. Cans of apple slices from the regular commercial run were retained for comparison with the batch processed products. Comparative evaluations were made based on USDA grading and organoleptic testing.

RESULTS AND DISCUSSION

Renovated Water Quality

Only those chemical, physical, and microbiological water quality indicators of health and aesthetic significance are summarized under this subsection. Other water quality parameters which are required to evaluate specific reuse objectives are presented under appropriate subsections of this paper. Parameters which were monitored as indicated on Table 1, but not discussed in this paper will be covered in detail in the final report on the Snokist reuse project[2].

In assessing the safety and sanitary quality of a water supply for potential use as a direct contact food process water, it is prudent to compare the properties of the water with the U.S. Drinking Water Standards. This approach in part will be made herein. However, when making such comparisons it must be realized, as pointed out by H. R. Pahren[19], that the primary drinking water standards, with the exception of NO_3, are based on the potential health effects from full time, long term consumption. In developing these standards it was assumed that 2 liters of water would be consumed daily for an entire lifetime. Obviously, the potential for this level of exposure from the consumption of processed foods does not exist. Thus, it is highly probable that a water of lower quality than drinking water can be safely used in the processing of food products.

The use of a process water of high microbiological quality is fundamental to the production of a safe and wholesome food product. As a result, the most important criteria for use in evaluating the feasibility of reusing treated process wastewater is the ability to produce a renovated water of high and consistent bacteriological quality. In this study total coliform organisms, fecal coliform organisms, and total plate counts were used as the primary indicators of microbiological quality. Staphyloccus, salmonella, yeast, mold, and mesophilic spore analyses were also used, but to a lesser extent.

Table 2 contains comparative microbiological data on Snokist's process water supply, biologically treated effluent, filtered effluent, and final renovated wastewater. Included in this table is also the bacteriological standards as recommended by The EPA Advisory Committee on the Revision and Application of the Drinking Water Standards[20]. These standards are more extensive than the current U.S. Drinking Water Standards[21], thus they were selected for use in this paper on all comparative water quality evaluations.

TABLE 2. WASTEWATER AND WATER SUPPLY BACTERIOLOGICAL QUALITY, 1976

Sample Station	Total Coliform (count/100 ml) n[1] - median - max.	Total Plate Count (count/ml) n - median - max.
Cannery Water Supply (unchlorinated)	4 - 1 - 1	3 - 8 - 58
Process Wastewater[2]	20 - 1.2×10^6 - 9.0×10^6	20 - 9.5×10^4 - 40×10^4
Biological Effluent	117 - 4.4×10^5 - 12×10^6	117 - 2.4×10^4 - 20×10^6
Filtered Effluent (unchlorinated)	117 - 3.4×10^5 - 13×10^6	117 - 2.3×10^4 - 11×10^6
Renovated Wastewater (chlorinated)	117 - 3 - 5.7×10^6	115 - 30 - 3×10^5
Drinking Water Stds.	N.A.- 1 - 4	N.A.[3]

[1] n = number of observations

[2] No sanitary wastes can enter system

[3] N.A. = Not Applicable

The bacteriological quality of Snokist's well water was excellent, as shown in Table 2. As previously mentioned, water from this source was the normal supply for all plant needs.

As indicated in Table 2, the biologically treated effluent had a poor microbiological quality. It is expected that the total coliforms present resulted from soil washed off the fruit during processing. There were also bacteria which produced a positive reaction in the fecal coliform tests; however, their low numbers and the fact that no salmonella or staphyloccus organisms were found throughout the 2 year monitoring program confirm that sanitary wastes are not discharged into the treatment system. Sources of these indicator organisms may have been the raw fruit, plant floor, or ducks and turtles that infrequently inhabit the treatment system.

Filtration did not improve the microbiological quality of the biological effluent. It may be possible, however, to improve the quality of this water with the addition of chemicals. Data comparisons between filter runs with and without the addition of alum indicate this potential, although the results were inconclusive. Further work is required in this area.

At Snokist, chlorination was used to disinfect the filtered effluent in an effort to produce a renovated water of high and consistent microbiological quality. Disinfection effectiveness by chlorination is dependent upon the maintenance of a chlorine residual, initial mixing, and contact time.

In this study mixing was provided by feeding a chlorine solution through a perforated pipe diffuser. The diffuser was located in the filter effluent line ahead of the chlorine contact tank.

The contact tank feed and discharge points were on diametric corners. To prevent short circuiting six baffles were located between the intake and discharge points. Based on a flow-through test, see Figure 2, this basin exhibits good plug-flow characteristics. Such characteristics are important to the disinfection efficiency.

Minimum chlorine contact periods provided in this study ranged from 1.3 to 2.6 hours. The lower value being the contact time when both filters were operating at their design filtration rate. This was the typical operating condition.

Two wastewater type amperometric continuous flow total chlorine residual analyzers were installed on Snokist's wastewater renovation system. One was used to monitor and control the residual immediately downstream of the chlorine diffuser. The second monitored the residual at the inlet to the reclaimed water pump which corresponds to the contact tank effluent.

As indicated by the summary contained in Table 2, the bacteriological quality of the chlorinated filter effluent was much improved over the straight filtered water. The summary indicates that the overall sanitary quality of the chlorinated effluent was highly variable (also see Figure 3). A large portion of this variability was the result of assessing disinfection requirements, although the high bacteriological counts normally occurred during periods of equipment or process malfunction.

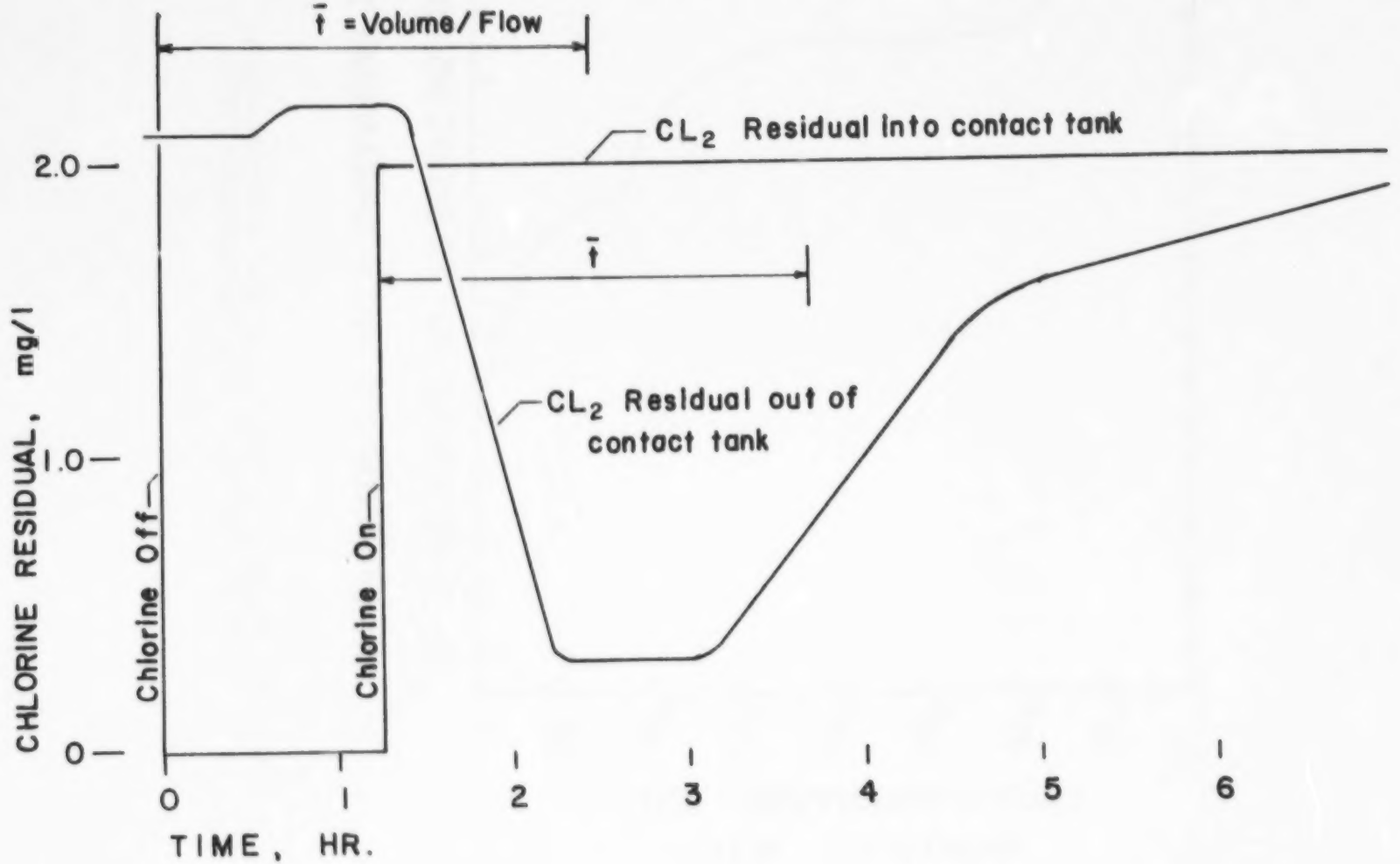

Figure 2. Chlorine contact time flow-through test.

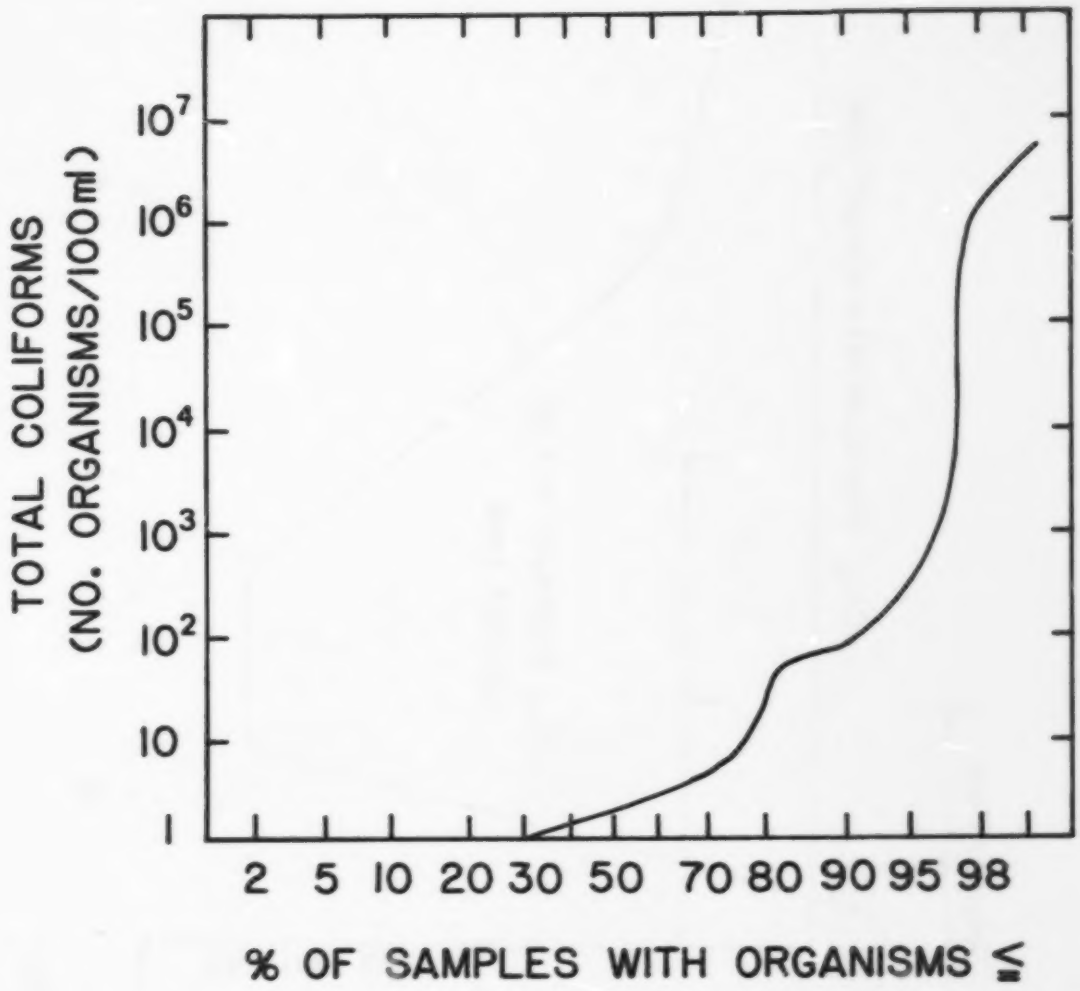

Figure 3. Frequency distribution of total coliforms counts in the chlorinated reclaimed wastewater (1976).

The typical approach to evaluating the effectiveness of chlorine disinfection is to express the reduction of coliform organisms as a function of contact time and chlorine residual. The large variation in input organisms to the Snokist disinfection system made organism reduction correlation unfeasible. The most consistent method for assessing the disinfection performance seemed to be the relation of effluent quality to the chlorine residual monitored at the reclamation pump inlet.

Disinfected effluent quality, coliform counts/100 ml, is shown in Figure 4 as a function of the total chlorine residual measured at the reclamation pump inlet (contact tank effluent). This figure indicates that 3 mg/l chlorine residual was adequate to assure very low levels of coliform bacteria in the reclaimed water. No positive counts were obtained when chlorine residuals were 3 mg/l or greater. Three relatively high counts were obtained during the '75 processing season, however, when the chlorine residual was in the 2 to 3 mg/l range. These high counts can probably be attributed to the chlorine residual control problems prevalent during that season. Occasionally during the '75 season the chlorine residual oscillated due to instability in the feedback control system. This problem was corrected prior to the 1976 campaign.

Positive fecal coliform counts were not observed in the renovated wastewater as long as a chlorine residual persisted throughout the contact tank.

The level of total bacterial content was assessed by use of the total plate count. The total plate count in the reclaimed effluent is shown in Figure 5. Marked improvement with chlorination is readily evident. It is also apparent that the maintenance of a chlorine residual of 3 mg/l or greater in the contact tank effluent reduced the bacterial content to less than 500 organisms/ml.

No staphyloccus or salmonella organisms were isolated in the renovated wastewater throughout this 2-year study.

Yeast, mold, and mesophilic spores were quantified in the reclaimed wastewater during the 76 processing season. Findings vs. chlorine residual measured at the time of sample collection are shown on Figure 6. Data analyses indicate that low levels of these organisms were present in the chlorinated filter effluent. As before, it appears that a chlorine residual of 3 mg/l, in all cases except one set of mesophilic spore analyses, reduced these indicators of sanitary quality to insignificant levels.

A summary of the chemical and physical characteristics of the renovated wastewater of health and aesthetic significance is presented in Table 3. For comparative purposes all of the standards recommended in 1973 by The EPA Advisory Committee on the Revision and Application of the Drinking Water Standards[20], along with the EPA proposed trihalomethane regulations[22] are included in this table.

The turbidity of the chlorinated filtered effluent varied appreciably as shown in Table 3 and illustrated in Figure 7. However, there were extensive periods, 2 to 3 months in duration, of low turbidity during the early portions of each processing season. For example the turbidity (nephelometric turbidity units) averaged 8.8 with a standard deviation of 4.5 between the dates of August 27 and October 4, 1975. All of the samples had turbidities of less

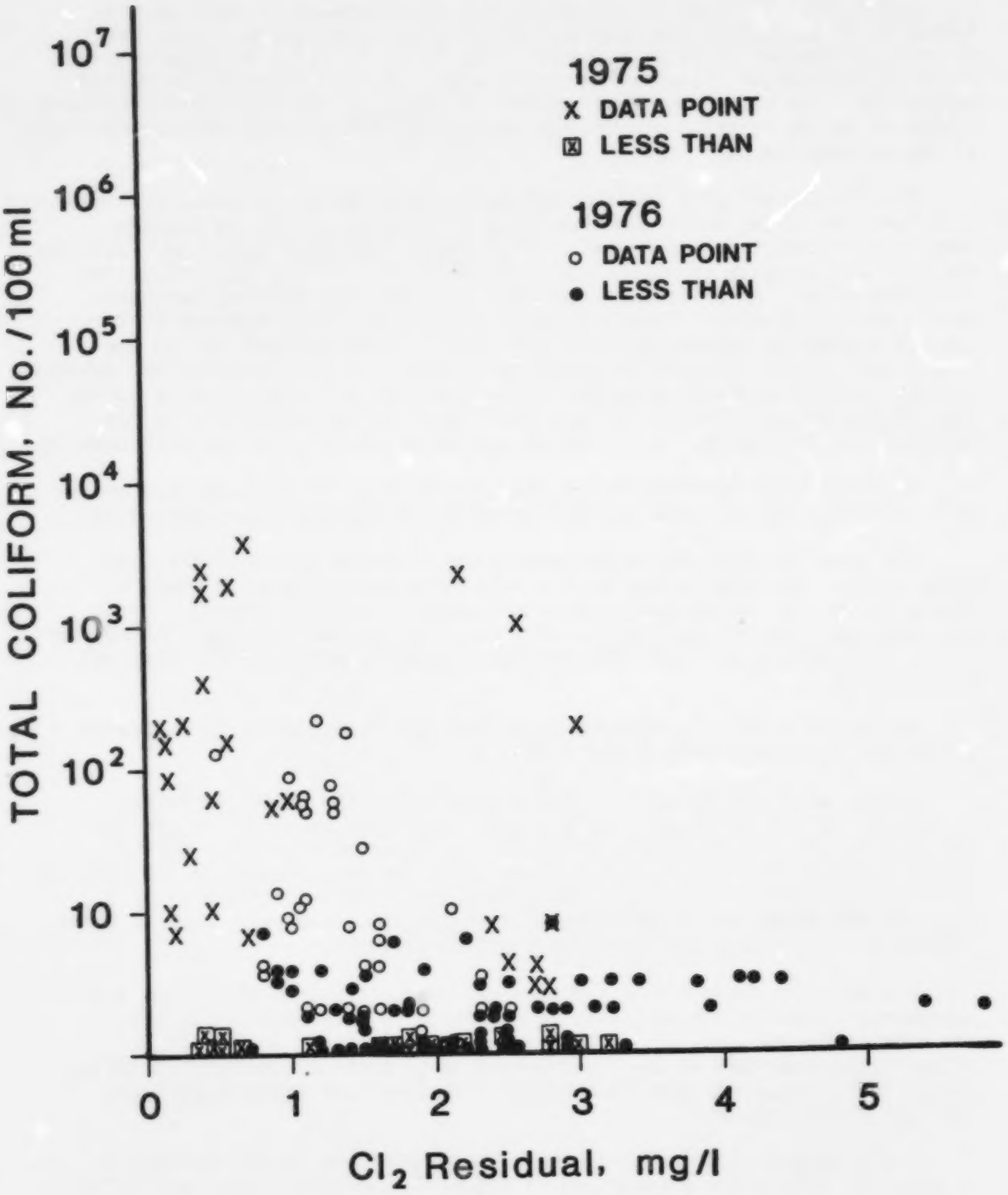

Figure 4. Total coliform counts versus total chlorine residual (1975, 1976).

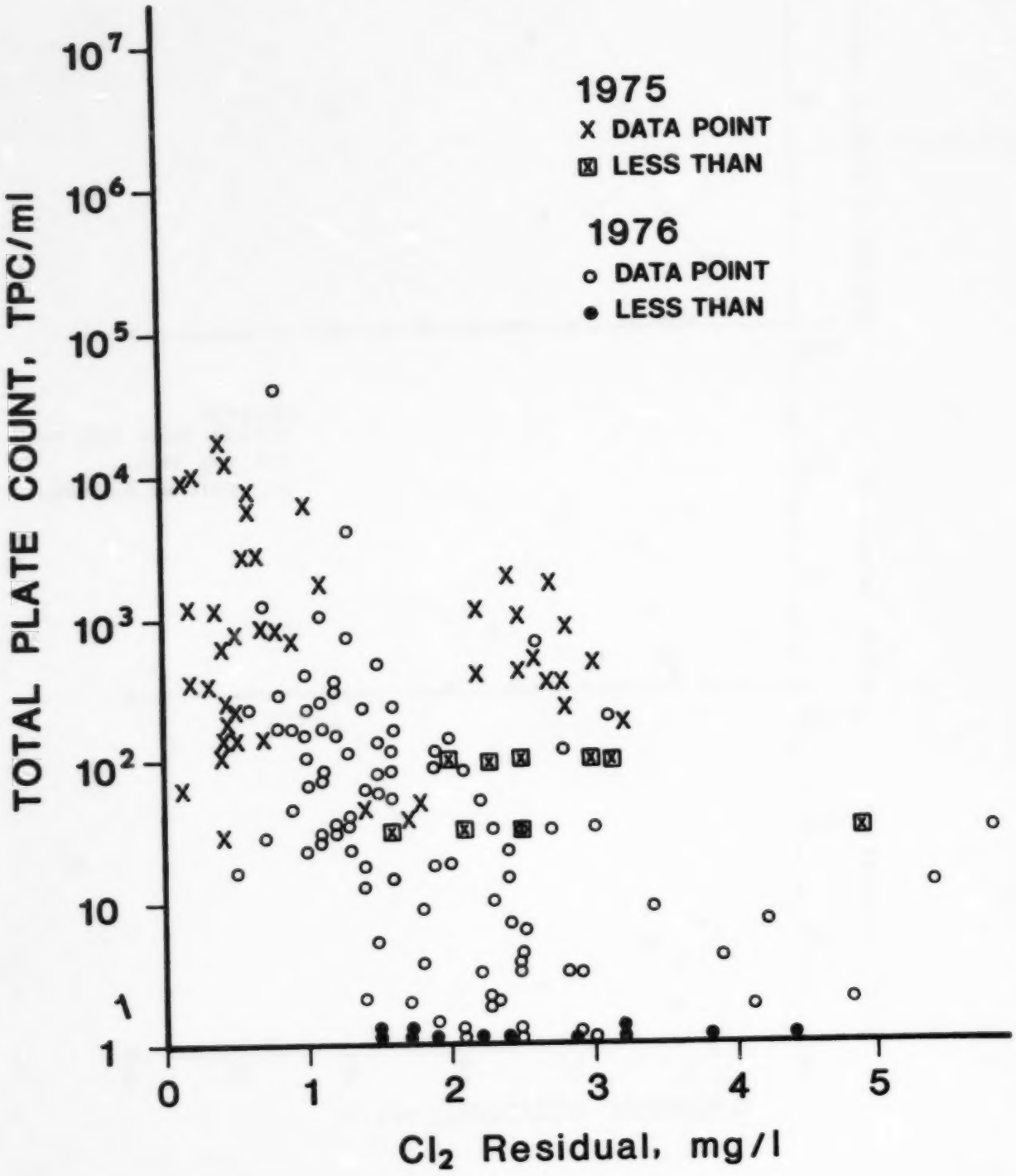

Figure 5. Total plate counts versus total chlorine residual (1975, 1976).

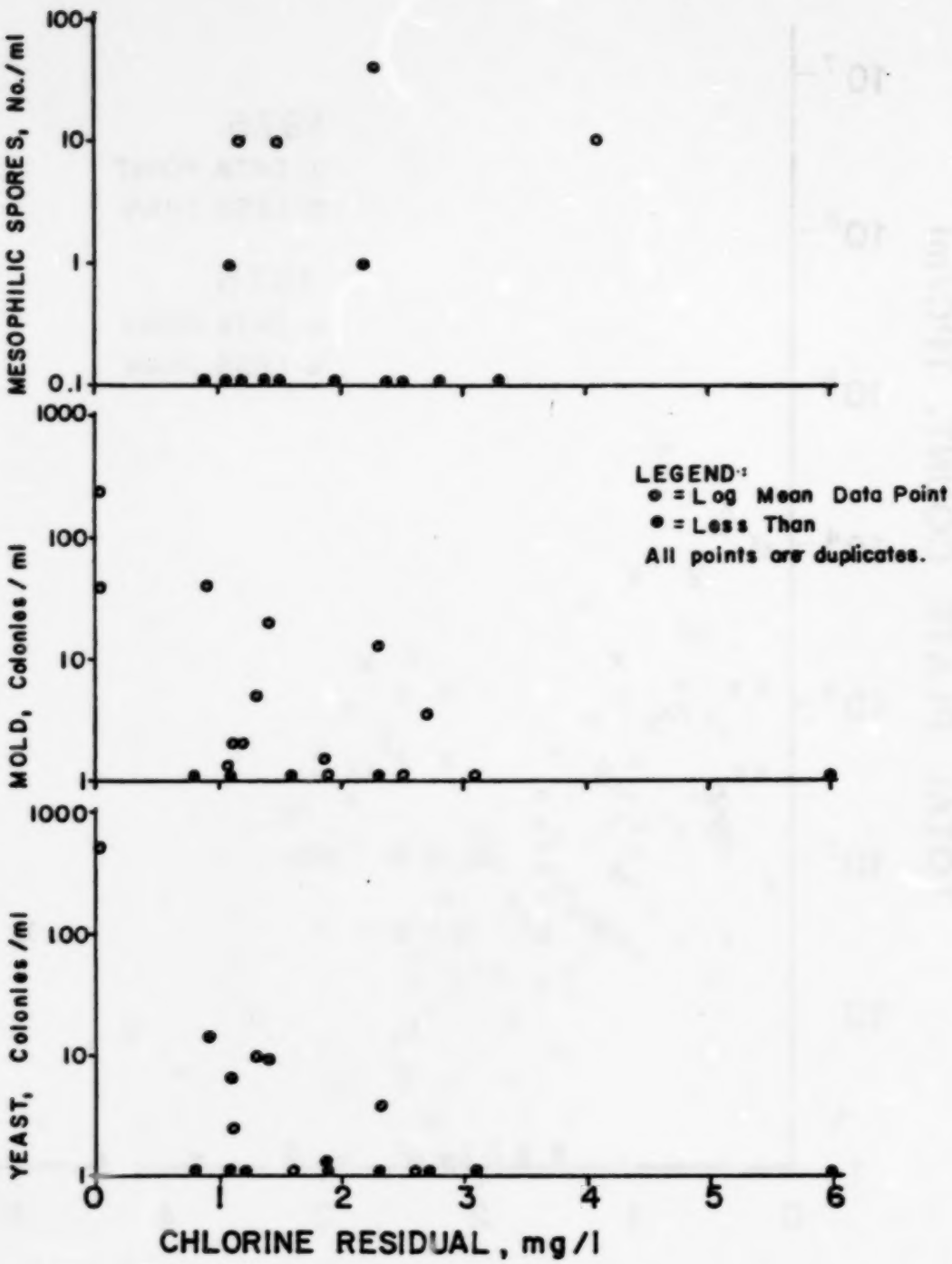

Figure 6. Yeast, mold, and mesophilic spore counts versus total chlorine residual (1976).

TABLE 3. RENOVATED WATER QUALITY COMPARISON TO DRINKING WATER STANDARDS, 1976

Parameter	Recommended Drinking Water Standards[1]	Primary Drinking Water Regulations[1]	Renovated Effluent n[2] - median - max.
Inorganic Chemicals:			
Arsenic	0.10	0.05	4 - <0.01 - <0.01
Borium	1.	1.	Not Measured (N.M.)
Cadmium	0.010	0.010	5 - <.02 - <.02
Chloride	250	-	22 - 41 - 112
Chromium	0.05	0.05	N.M.
Copper	1	-	5 - <.015 - <.018
Cyanide	0.2	-	N.M.
Flouride	1.2 - 1.5[4]	1.4 - 2.4[4]	N.M.
Iron	0.3	-	5 - <.15 - <.25
Lead	0.05	0.05	5 - 0.01 - 0.02
Manganese	0.05	-	5 - <0.01 - <.025
Mercury	0.002	0.002	5 - .0004 - .0026
Nitrate (as N)	10.	10.	40 - 0.48 - 15.4
Selenium	0.01	0.01	N.M.
Silver	0.05	0.05	N.M.
Sodium	20 - 270	-	5 - 49.1 - 112.5
Sulfate	250	-	24 - 18 - 60
Zinc	5	-	5 - 0.28 - 0.62
Organic Chemicals:			
Chlorinated Hydrocarbons			
Aldrin	0.001	-	Not Detected
Chlordane	0.003	-	Not Detected
DDT	0.05	-	Not Detected
Dieldrin	0.001	-	Not Detected
Endrin	0.0005	0.0002	Not Detected
Heptachlor Epoxide	0.0001	-	Not Detected
Lindane	0.005	0.004	8 - N.D. - 1.6×10^{-5}
Methoxychlor	0.1	0.1	Not Detected
Toxaphene	0.005	0.005	Not Detected

TABLE 3. (Continued)

Parameter	Recommended Drinking Water Standards[1]	Primary Drinking Water Regulations[1]	Renovated Effluent n[2] - median - max.
Chlorophenoxys			
2,4-D	0.02	0.1	N.M.
2,4,5-TP	0.03	0.01	Not Detected
Organophophates (as)			
Parathion	0.1	-	Not Detected
Carbon-Chloroform Extract	0.7	-	N.M.
Carbon-Alcohol Extract	3.0	-	N.M.
Trihalomethanes	-	0.10[3]	5 - 0.01 - 0.03
Physical:			
Turbidity	1 unit INTU)	1 unit	116 - 12 - 300
Color	15 units	-	24 - 25 - 90
Odor	3 units	-	N.M.
MBAS	0.5 mg/l	-	6 - <0.1 mg/l - <0.1 mg/l
Microbiological:			
Total Coliform	1/100 ml	1/100 ml	117 - <3 - 5.7×10^6/100 ml
Total Plate Ct.	500/ml	-	115 - 30 - $>3.0 \times 10^5$/ml

[1]Units are mg/l unless otherwise noted

[2]n = number of observations

[3]Proposed primary drinking water regulation [22]

[4]Varies depending on annual average of the maximum daily air temperature

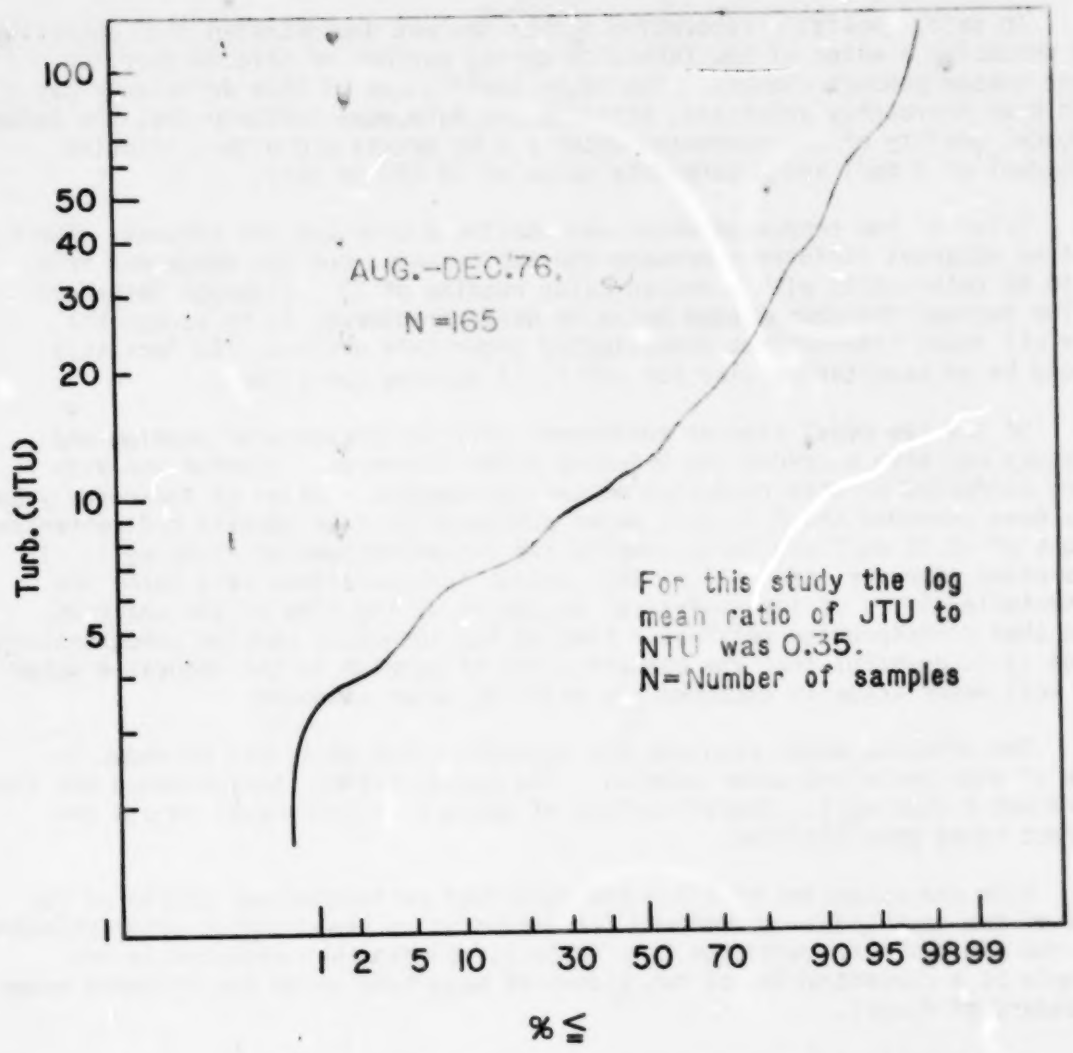

Figure 7. Turbidity frequency distribution of renovated wastewater.

than 20 NTU's. Except for one short period of upset, the corresponding 76 values were even lower, with all of the values being less than 10 NTU's.

To date, Snokist's renovation system has not demonstrated the capability of producing a water of low turbidity during periods of cold weather, or late season product changes. The reuse implication of this deficiency has not been thoroughly addressed, although the data does indicate that the bacteriological quality of the renovated water can be maintained with a chlorine residual of 3 mg/l and a turbidity value of 20 NTU or less.

Color of the renovated water was monitored over the two seasons. There was no apparent difference between the two seasons, and the range was from 5 to 90 color units with a median color reading of 25. Although this mean value exceeds the recommended drinking water standards, it is acceptable for all reuse alternatives investigated under this project. In fact this would be an acceptable color for all fruit canning operations.

Of the ten metal species monitored, only the presence of cadmium and mercury may have exceeded the Drinking Water Standards. Cadmium analyses were conducted on nine renovated wastewater samples. Seven of these analyses may have exceeded the 0.01 mg/l water standard, as four samples had concentrations of <0.03 mg/l and three samples had concentrations of <0.02 mg/l. It was noted, however, that all of the cadmium concentrations were below the detectable limits of the analytical equipment at the time of the analyses, and that corresponding well water sampled had identical cadmium concentrations. Thus it is doubtful that the concentration of cadmium in the renovated water or well water actually exceeded the drinking water standard.

The drinking water standard for mercury, 0.002 mg/l, was exceeded in one of nine reclaimed water samples. The concentration that exceeded the standard was 0.0026 mg/l. Concentrations of mercury at this level should not affect reuse possibilities.

With the exception of 2,4-D the reclaimed wastewater was monitored for all of the pesticides recommended for inclusion in the drinking water standards by the EPA advisory committee (see Table 3). Lindane was detected in one sample at a concentration of two orders of magnitude below the drinking water standard of 4 µg/l.

The analytical procedure used to identify and quantify the above organochlorine pesticides also allowed for scanning the renovated wastewater for the presence of a large number of other similar pesticides. These compounds were: CDEC, simazine, dichlone, 1-hydroxychlordine, dacthal, thiodan I and II, DDA(ME), folpet, kepine, dilan I and II, tedion, atrazine, dyrene, chlorobenside, captan, and mirex. None of these compounds were found.

In addition to the previously mentioned pesticides, the reclaimed water was also checked for pesticides known to have been applied to the fruit processed by Snokist or thought to be ubiquitous in nature. These compounds monitored were: BHC, DDD, DDE, heptachlor, perthane, endosulfan, sevin, benomyl, diphenylamine, plictran, karathane, omite and maneb. A total of only four positive results were obtained from this monitoring program.

BHC was present at concentrations of 0.008 and 0.28 µg/l, once in 1975 and again in 1976. It is assumed that the presence of BHC at these levels

is of no health significance due to the fact that the insecticidal properties of this compound are due to the gamma isomer Lindane[23], and the concentrations of BHC detected in the renovated water were well below the lindane drinking water standard of 4 µg/l.

Diphenylamine was detected in two samples, concentrations were reported at 1-2 and 2-4 µg/l. Diphenylamine was applied to the apples prior to storage for mold control. The reported concentrations are subject to uncertainty due to difficulty encountered during the analysis since there is no known procedure for its determination in a water matrix. However, it is apparent that additional monitoring for this compound is warranted.

The presence of PCB's with molecular weights of 1242, 1248/1254 and 1260 was also monitored. Positive results were obtained for molecular weights 1248/1254 in the range of from <0.010 to 0.065 µg/l. This material was detected at approximately the same concentration in both the well and reclaimed water. It is doubtful that the presence of PCB's at these levels are of public health significance.

The reclaimed effluent was monitored for six organohalides throughout the 1976 processing seasons. A summary of these data by sampling dates is presented in Table 4. Also included, therein, are the chlorine residuals and total COD values of the renovated wastewater. Based on these data no firm conclusions can be drawn regarding the concentration of precursor organics, chlorine residuals and the generation of trihalomethanes. However, in general it appears that the sum of the trihalomethanes may be a function of chlorine residual and the concentration of organic precursors. The concentrations of total trihalomethanes observed were well below the EPA proposed regulations of 100 µg/l[22].

In summary, Snokist's renovated process wastewater was shown to be of excellent physical and chemical quality from a public health standpoint. Bacteriological quality was also acceptable when the chlorine residual was maintained at 3 mg/l or greater, after a contact period of approximately one hour. However, as shown in Figures 7 and 8, the system has not been able to produce a consistent quality of water in terms of some aesthetic properties. This weakness requires correction before this water can be used, on a continuous year round basis, in areas requiring the use of a high grade water.

Reuse Testing

Equipment Cleaning--

During the 1975 processing season, comparative cleaning of belts on the peeler line was conducted on six occasions with reclaimed water and house steam, and with house water and house steam. Swab tests for total plate counts were conducted on the equipment following cleaning. There were four separate samples, each analyzed in duplicate from each belt washed with either the house or reclaimed water and steam. Table 5 contains a summary of these data. Tests were conducted between September 19th and December 20th.

There is a difference between the results using the house and reclaimed water for washing equipment, although it is not statistically significant at the 90 percent confidence level. This difference can probably be explained

TABLE 4. ORGANOHALIDES, CHLORINE RESIDUALS AND PRECURSOR ORGANICS IN THE RECLAIMED WASTEWATER, 1976 PROCESSING SEASON

	Sampling Date					
	9/21	10/21	11/16	12/14		3/8
1,2-Dichloroethane (µg/l)	N.D.	N.D.	N.D.	N.D.[1]	N.D.	N.D.
Carbontetrachloride (µg/l)	1	1	1	N.D.	N.D.	1
Bromodichloromethane (µg/l)	1	1	1	N.D.	N.D.	1
Dibromochloromethane (µg/l)	2	1	1	1 to 3	1 to 3	1
Tribromomethane (µg/l)	N.D.	1	N.D.	N.D.	N.D.	1
Trichloromethane (µg/l)	8.2	5.8±0.6	24.8±2.3	1.5±0.2	1.6±0.2	13.4±2
Total Trihalomethanes[2] (µg/l)	11	7	27	4		15
Chlorine Residual (mg/l)	2.9	1.2	3.3	1.6		1.5
COD (mg/l)	24	24	44	49		60

Notes: N.D. = Not Detected
1 = Duplicate samples
2 = Approximate sum of the 4 trihalomethanes

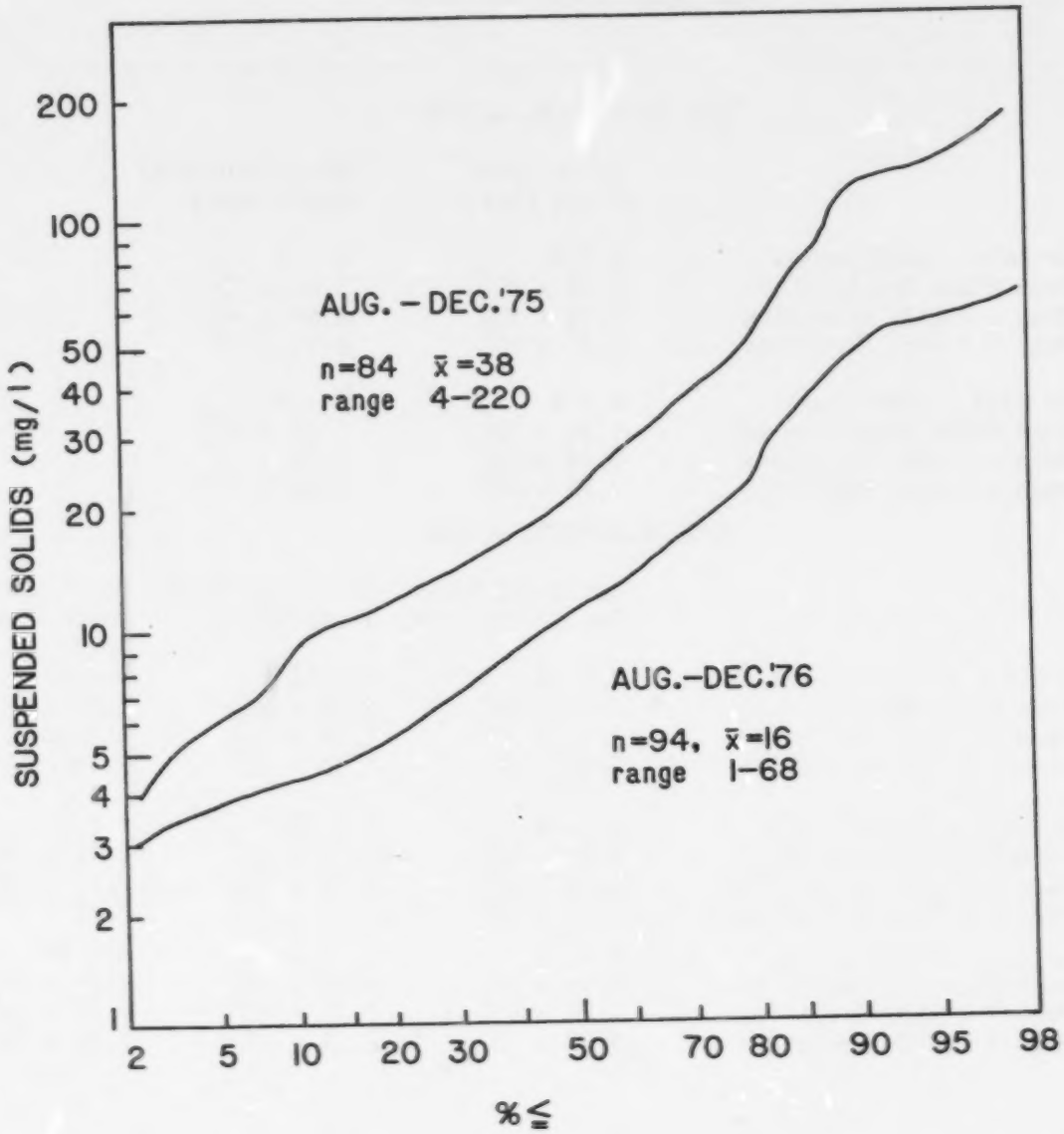

Figure 8. Suspended solids frequency distribution of the reclaimed wastewater.

TABLE 5. SANITARY CONDITION OF PROCESSING EQUIPMENT CLEANED WITH VARIOUS COMBINATIONS OF WATER AND STEAM, AND HOUSE WATER AND STEAM

1975 PROCESSING SEASON

	House Water House Steam	Reclaimed Water House Steam
Peeler Belt - Swab Counts	n = 6	n = 6
Log Mean Plate Count/100 ml	1.24×10^5	3.26×10^5
Log Mean - 1 Std. Deviation	1.10×10^4	3.64×10^4
Log Mean + 1 Std. Deviation	1.40×10^6	2.92×10^6
Shaker Belt - Swab Counts	n = 6	n = 6
Log Mean Plate Count/100 ml	1.34×10^5	1.03×10^6
Log Mean - 1 Std. Deviation	6.74×10^3	1.09×10^5
Log Mean + 1 Std. Deviation	2.76×10^6	9.86×10^6

1976 PROCESSING SEASON

	Reclaimed Water Reclaimed Steam	Reclaimed Water House Steam	House Water House Steam
Waste Slide - Swab Counts	n = 20	n = 22	n = 22
Log Mean Plate Count/100 ml	1.30×10^5	2.08×10^5	1.45×10^5
Log Mean - 1 Std. Deviation	3.23×10^4	4.05×10^4	5.35×10^4
Log Mean + 1 Std. Deviation	5.20×10^5	1.06×10^6	3.92×10^5
Peeler Belt - Swab Counts	n = 10	n = 10	n = 10
Log Mean Plate Count/100 ml	8.03×10^5	3.09×10^5	1.43×10^5
Log Mean - 1 Std. Deviation	2.14×10^5	2.70×10^4	2.83×10^4
Log Mean + 1 Std. Deviation	3.01×10^6	3.54×10^6	7.23×10^5
Shaker Belt - Swab Counts	n = 10	n = 10	n = 10
Log Mean Plate Count/100 ml	3.68×10^4	8.01×10^3	2.58×10^3
Log Mean - 1 Std. Deviation	1.36×10^4	7.33×10^5	2.86×10^5
Log Mean + 1 Std. Deviation	9.97×10^4	8.74×10^5	2.33×10^5

by the differences in chlorine residuals of the two wash waters. The mean chlorine residual in the house water during the cleanup periods was 4.1 mg/l while the reclaimed water residual averaged 0.3 mg/l.

During the 1976 processing season, three parallel pear processing lines were separately washed using: reclaimed water and steam generated from reclaimed water; reclaimed water with house steam; and house water with house steam. During these washing trials the chlorine residuals in the house and reclaimed water were controlled so the mean residual chlorine in both waters was equal and averaged 0.9 mg/l. The '76 results are also shown on Table 5. Tests were conducted between October 1st and November 15th. Based on an analysis of variance, there was not a significant difference between the sanitary condition of any of the test lines.

The waste slide data (see Table 5) resulted from biweekly monitoring of the waste peel and core slides. Three slides were washed with various treatments, as indicated in Table 5, over the entire 6 weeks of study without intervening washdowns using house steam-water. The purpose of this test was to determine if sanitation problems developed after prolonged use of reclaimed water. Based on the data collected, there was no trend in the results, nor was there a significant difference between the sanitary condition of the three waste slides.

Product Cleaning and Conveying--

Use of the reclaimed water for initial conveying and cleaning of fruit was conducted during the 1976 processing season. The water was initially used during a portion of the peach processing season and compared with house water used during the remainder of the peach processing. The results of the total plate count analyses are shown on Figure 9. It is visually apparent that the sanitary quality of the fruit was not affected by the use of reclaimed water. Throughout this test the house water was not chlorinated and the chlorine residual in the reclaimed water averaged 0.5 mg/l. Peach cleaning tests were conducted from September 20th through the 25th.

House water and reclaimed water were alternately used in the apple dump and conveying area for about a 5 week period. The results of total plate count analyses on the fruit during these dumping operations are shown on Figure 10. As with peaches, the sanitary condition of the fruit was not adversely affected by the use of the renovated wastewater. Again, as with peaches, the house water was unchlorinated and the chlorine residual of the reclaimed water averaged 3.0 mg/l. The apple cleaning studies were performed through December, part of January, and into the March processing period.

Direct Contact Container Cooling--

On October 24th, 1975, and September 15th, 1976, contact container cooling with reclaimed water was performed on a trial basis. The quality of the water used during these experiments is shown in Table 6. In each trial approximately the same number of cans was cooled in house water and retained for use as a control. During both test periods a chlorine residual of 1 mg/l was maintained in the house water at the point of discharge from the cooler. However, chlorine at this level was only maintained in the reclaimed water during the '76 trial.

The 1975 direct contact container cooling trial produced 1,150 cans of pears cooled in each of the two waters. One hundred twenty cans from

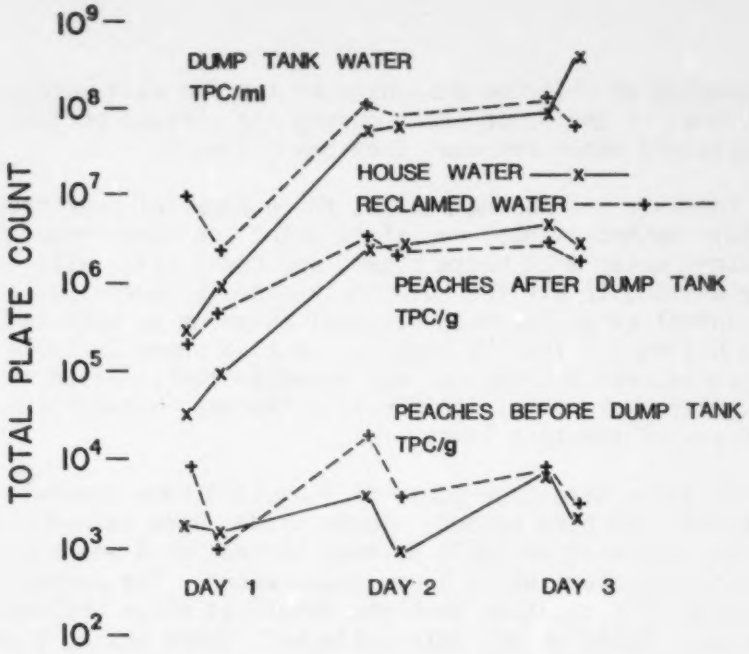

Figure 9. Total plate counts on fruit and in dump tank using reclaimed and house water for peach dumping and conveying (1976).

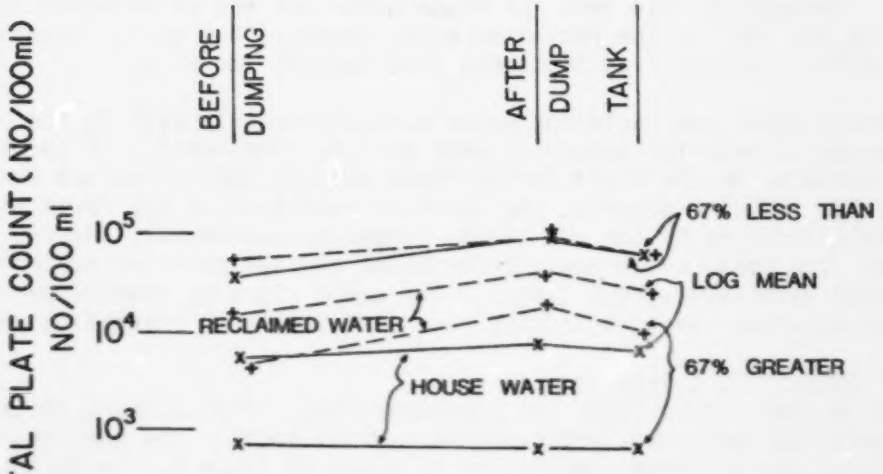

Figure 10. Total plate counts recovered from fruit using reclaimed water and house water for apple dumping and conveying (1976).

TABLE 6. QUALITY OF RECLAIMED WATER USED IN COOLING TRIALS

Parameter	1975	1976
COD	56	17
pH	7.5	7.1
SS	18	5
Cl_2 Residual[1]	0.6	0.7[2]
Total Coliform	1900	80
Total Plate Count	5900	140

[1]Chlorine residual measured at discharge from chlorine contact tank.

[2]Cl_2 was added to maintain a 1 mg/l residual in the water at its point of discharge from the can coolers.

each of the treatments were incubated at elevated temperatures for a period of time to simulate long term storage. The remainder of the cans were retained in the cannery warehouse at approximately 18°C. The 1976 cooling trial produced about 3,000 cans of pears from each treatment, i.e., house water vs. reclaimed water. Approximately 110 cans from each of these treatments were used in an accelerated storage trial and the remainder stored in Snokist Growers' warehouse at approximately 18°C.

The 1975 accelerated storage samples were maintained at 30°C for 60 days. At the end of this period all cans were checked for vacuum and pH and approximately one third of the cans from each treatment were examined microscopically for biological contamination. The average vacuum for the cans cooled in house and reclaimed water was 7.2 inches and 8.7 inches of Hg, respectively. The ranges were 0-11 inches and 5-14 inches, respectively. The low vacuums, less than 3 inches, from the house water group occurred in dented cans. The pH ranges for the house and reclaimed water, respectively, were 3.85 to 4.10 and 3.85 to 4.05. The microscopic examination results were negative for all cans checked and all cans were found to be commercially sterile.

The 1976 accelerated storage samples were retained for 6 months at 35°C, which simulates a minimum of 18 months of storage. All of the cans were checked for vacuum, pH, spotting and corrosion. No swollen or leaking containers were detected which indicates that the product was free of spoilage organisms. All product samples had normal color and texture. All containers were free of spotting and corrosion both externally and internally. The vacuum in the reclaimed water and house water cooled cans averaged 8.8 and 9.4 inches Hg, respectively. The range was 3.0 to 13.5 and 2.5 to 17.0 for the reclaimed and house water cooled containers, respectively after removal of dented cans from the test. The pH in the reclaimed water and house water cooled containers ranged from 3.6 to 4.0 in both cases.

All of the cans stored at ambient warehouse conditions from the '75 and '76 trial cooling runs were inspected after one year of storage. The cans from the '75 runs were also inspected after a storage of 6 months. Neither leaking or swelling were noted in any of the approximately 8000 cans inspected.

By referring to Table 6 it is apparent that the contact container cooling trials were conducted during periods when the bacteriological quality of the reclaimed effluent was not of high quality. However, even when using this water there were no failures of containers nor contamination of processed fruit. Thus, it is concluded that the reclaimed water can be safely used for direct contact container cooling if the total coliform counts approach the limit specified in the U.S. Drinking Water Standards.

Boiler Feed--

The suitability of the reclaimed effluent for steam generation in the cannery is compared in Table 7 to the house tap water and the maximum concentrations recommended for low pressure boiler feed water. There doesn't appear to be any significant difference between the suitability of the house tap water and the reclaimed water for boiler feed according to the concentration of silica, aluminum, iron, manganese, copper, pH, MBAS or dissolved oxygen. The dissolved solid of the reclaimed water were significantly higher than

TABLE 7 . BOILER FEED SUITABILITY

Constituent	Max. Concentration[1]	House Tap Water[2]	Reclaimed Water[2]
Silica (SiO_2),mg/l	30	2.4 ± 0.3	2.5 ± 0.9
Aluminum (Al),mg/l	5	<0.1 - 0.1	<0.1 - 2.2[3]
Iron (Fe),mg/l	1	<0.2	<0.2
Manganese (Mn),mg/l	0.3	<0.01	<0.01
Copper (Cu),mg/l	0.5	<0.02	<0.02
Dissolved Solids, mg/l	700	120 ± 11	290 ± 99
Alkalinity ($CaCO_3$),mg/l	140	61 ± 3	86 ± 62
Hardness ($CaCO_3$),mg/l	20	41 ± 6	30 ± 10
pH, units	8-10	8.1 - 8.3	7.15 ± 0.45
MBAS, mg/l	1	<0.01	<0.1
COD, mg/l	5	5-10	<40,80% of 1976 Pear
Dissolved Oxygen, mg/l	2.5	2.5 - 3.5	7-12
Suspended Solids, mg/l	10	<1	<10,70% of 1976

[1] Maximum recommended concentration before adding substances used for internal conditioning. From Water Quality Criteria, FWPCA, 1968, Table V-5, for low Pressure Boiler Feed Water (0 to 150 psig).

[2] These columns contain the Mean ± Standard Deviation, or the Range of values observed.

[3] Al in Reclaimed Effluent <0.1 - 0.1 if Alum not used, 1.6 - 2.2 if Alum being used.

in the house tap water, although both were less than the maximum recommended concentration. The alkalinity of the reclaimed water was higher than that of the tap water and exceeded the recommended level a portion of the time. The period when the alkalinity exceeded that recommended occurred during and for approximately two weeks following the use of lye for peeling peaches. During the 1975 and 1976 processing seasons the maximum alkalinity of the renovated wastewater was in the range of 270 to 300 mg/l. The alkalinity exceeded 200 mg/l for two weeks during each season and otherwise did not exceed the 140 mg/l recommended limitation. The hardness of the reclaimed water was less than for the house tap water. The hardness concentrations of both waters exceeded the 20 mg/l recommended concentration. Snokist normally uses an ion exchange system to reduce hardness in the boiler feed water. The reclaimed water would not exhaust the ion exchange system as rapidly as the tap water and, therefore, would provide a more economical boiler feed from the hardness standpoint.

The COD of the house tap water was at the minimum concentration measurable. The reclaimed water COD exceeded the recommended 5 mg/l virtually all of the time. During the 1976 pear processing season, when the reclaimed effluent was of the most consistent and best level of quality, the COD was less than 40 mg/l 80% of the time. The period when the COD exceeded 40 mg/l was principally during one week which followed an upset of the biological treatment system. Suspended solids in the reclaimed effluent were much greater than those in the house tap water. However, the suspended solids in the reclaimed water were within the recommended 10 mg/l maximum concentration 70% of the entire 1976 processing season, and for a greater proportion of the time during the pear processing portion of the season.

Equipment Cleaning (Steam)--Reclaimed water was used during six weeks of the 1976 processing season for feed to a portable steam generator to produce steam for pilot uses inside the cannery. During the period from the week of October 4th through the week of November 8th, steam generated from the reclaimed water was used in conjunction with reclaimed water to clean a waste peel and core slide. This slide was cleaned on a daily basis in parallel with waste slides cleaned using house steam and reclaimed water, and house steam and house tap water. This reclaimed water steam and reclaimed water couplet was also used on a weekly basis to clean equipment belts in parallel with the other two treatments. The results are reported under "Equipment Cleaning" above.

Exhausting--On October 15th and 23rd, 1976, pears were batch processed through the cannery exhaust box using steam produced from the reclaimed wastewater. The canned pears were then capped, cooked and cooled. These cans were retained for comparison with pears exhausted under normal continuous conditions using house steam. Comparisons were based on organoleptic evaluations of the final product.

The quality of the reclaimed water used as boiler feed was excellent throughout these runs. Total coliform counts were <1/100 ml, plate counts ranged from <1 to 3/ml, and turbidity ranged from 3 to 4 NTUs. Suspended solids were 8 and 13 mg/l on the 2 dates, respectively, and corresponding COD values were 39 and 28 mg/l.

Results of the organoleptic evaluations via the triangle test on the October 15th samples indicated that there was a highly significant difference ($p = 0.01$) between the experimental and control samples. However, due to comments by the tasters, the triangle test was conducted a second time. Results on this test indicated no significant difference between samples. Results from the triangle test conducted on the October 23rd sample also indicated no significant difference between samples. It was concluded, taking into account all organoleptic results, that there was no significant difference in the sensory attributes between the control and test samples. This was in spite of the differences in processing between these samples.

Applesauce Cooking--Applesauce cooking trials with steam generated from the reclaimed water were conducted on November 29th and 30th of 1976. Comparisons were made between batch processed applesauce using reclaimed water steam and house steam, and applesauce processed on a continuous basis using house steam. Product from each of these six runs was graded according to the standard scoring procedures for the cannery. Samples from each of the runs were also tested organoleptically. The quality of the renovated wastewater during these trials was as follows on the 2 days, respectively: pH, 7.1 and 7.2; suspended solids, 52 and 44 mg/l; chlorine residual, 2.2 and 1.5 mg/l; total coliform, <2/100 ml; total plate count, 190 and 30/ml.

The three comparative treatments (continuous cooking for a control, house steam batch cooking and reclaimed steam batch cooking) resulted in grading scores of 96, 89 and 90, respectively. The control was different from the house steam and reclaimed steam scores at the 99.9 percent significance level. The house steam and reclaimed steam scores were not significantly different at the 95 percent level. The most significant categories in which the control and the house steam and reclaimed steam treated samples were different were in color and flavor.

The organoleptic evaluation on the triangle difference test was conducted using an eighteen member taste panel. Each panel member conducted two triangle difference tests, one between the control and the house steam treated samples, and the second between the house steam and reclaimed steam treated samples. In every case the correct responses were significantly different at the 99.9 percent level. Comments from the panel members indicated that the house steam treated applesauce was darker than the control sample. Between the house steam and reclaimed steam samples, notes indicated that the house steam treated samples were darker. The organoleptic evaluations did not indicate which treatment was preferable, only that the panel was able to distinguish the difference between the samples. The panelists were forced to wear dark glasses during the testing so the difference in taste was their principle means for detecting difference. The analyst who conducted the test indicated that the difference in color and the difference in taste may have been related to carmelization which probably occurred due to the lack of careful and close control over the temperature in the cooking vessel during the trial batch runs. It was also noted that the finish or texture varied between the samples. This could also have been influenced by the cooking procedure.

As nearly as could be determined from the organoleptic evaluations, there were no differences in the product which related to the origin of the water used in generating the steam. However, it would be impossible to state that the steam generated from the reclaimed or the house water are equivalent since the method of processing influenced the product greater than did the steam source.

Blanching--Trials with reclaimed steam for sliced apple blanching were conducted on November 22nd and 23rd, 1976. On each of these days, control samples were drawn from the continuous processed blanched apples. Samples were also drawn from batch blanched apples using house steam and using steam from reclaimed water. These samples were graded according to Snokist Growers' normal grading procedures. Additional samples of the canned fruit were used for organoleptic evaluation. The reclaimed effluent quality used for generating steam for sliced apple blanching was as follows for the two respective days: pH, 7.1 and 7.2; suspended solids, 17 and 18 mg/l; chlorine residual, 0.6 and 1.0 mg/l; total coliform, <1 and 28/100 ml; total plate count, 30 and 460/ml.

The mean grading scores for the control processed fruit, the fruit blanched with house steam on a batch basis, and fruit blanched with reclaimed water steam on a batch basis were 79, 84 and 79, respectively. The house steam batch processed fruit score was significantly different from the control and the reclaimed steam processed fruit at the 95 percent level. There was no significant difference between the control and the reclaimed steam processed fruit grading scores. The uniformity of the control fruit was distinguishably less than either of the batch processed fruit, and the character of the reclaimed steam processed fruit was graded lower than either of the others.

The organoleptic evaluation was conducted by an eighteen member taste panel using the triangle test; each member participated in two tests. The results of these tests indicated that a significant difference existed between the control fruit and that processed on a batch basis with house steam, and between the fruit processed on a batch basis with house steam and reclaimed steam. The specialist who conducted the test again attributed the differences to texture and degree of caramelization which was felt to be unrelated to the origin of the steam. The principle differences were judged to be influenced by batch to batch variability in the fruit processed and the processing variables such as holding time and temperature.

As with the use of the reclaimed steam for applesauce cooking, its use for sliced apple blanching could not be finally judged based on these tests. Apparently the differences in processing variables unrelated to steam source had greater effect on the product quality than the source of water for steam generation.

Economic Feasibility

The cost of reclaiming spent process water at Snokist was $50,000/year or $0.23/cu m ($0.86/1000 gal). These expenditures include: the amortized capital cost (15 yrs at 8%) of the effluent renovation system and the inplant renovated water distribution system, and the operation and maintenance cost. The amortized cost was approximately 90% of the total cost. Unit costs, $/cu m, were based on 100% utilization of the renovation system at its designed capacity of 1900 cu m/day (0.5 MGD).

Direct costs to Snokist, if the renovation system was not installed, would be incurred for the expansion of their water supply and for pumping this additional effluent to the river. The cost to expand Snokist's water supply by approximately 1900 cu m/day, assuming a new well at $150,000, would be $0.09/cu m ($0.32/1000 gal). This cost includes items previously mentioned.

It appears that Snokist's wastewater renovation system produces a reusable grade of water at an economically acceptable price. However, in their case the effluent reclamation/reuse system can not be justified economically on a water supply basis alone due to the availability of an adequate supply of high quality ground water. However, it is very likely that the system can be justified on the basis of meeting future effluent permit requirements.

SUMMARY

A 2 year study was conducted to evaluate the techno-economic feasibility of reclaiming biological effluent for reuse as a finished process water supply. The effluent was reclaimed by filtration through mixed media pressure filters and subsequently disinfected with chlorine. The wastewater treated in the biological system was generated from the processing of high-acid foods (apples, peaches and pears), and it was free of sanitary wastes. The final processing of these food products was by heat treatment in hermetically sealed containers.

Water renovated during this study was evaluated for use in initial product cleaning and conveying, equipment cleaning, direct contact container cooling, and boiler feed. Steam generated from the reclaimed water was used on a trial basis for equipment cleaning, exhausting, cooking and blanching.

The renovated water was found to be of high quality. In fact, it consistently met the current and proposed U.S. Primary Drinking Water Regulations, except for turbidity and bacterial counts, for all of the primary parameters which were monitored. Even the bacterial regulation could be met with adequate chlorination. However, the turbidity of the reclaimed water was highly variable. It appears, based on the FDA regulations requiring the use of a water which is safe and of adequate sanitary quality, that the continuous inplant reuse of a renovated wastewater will require that this water have a consistent and relatively low turbidity level. This requirement is based on the fact that such a characteristic will greatly assist in maintaining the bacterial integrity and aesthetic quality of the reclaimed wastewater.

When assessing the feasibility of wastewater reclamation/reuse within a food processing establishment, it is reasonable, based on the excellent human health safety record associated with the U.S. public drinking water supplies, to compare the quality of the renovated water to the U.S. Drinking Water Standards. However, in making such comparisons it must be remembered that all of the physical and chemical primary drinking water standards, with the exception of NO_3, were predicated on the potential health effects of full-time long term consumption, 2 l/day for a lifetime. It is intuitively obvious that the ingestion of any one of these pollutants to this magnitude is highly improbable through the consumption of fruits that have been processed in their own reclaimed process wastewater. Should we, instead of relying on regulations requiring the use of potable water, or such subjective regulations as. ."shall be safe and of adequate sanitary quality. .", establish water quality standards for each unit operation based on the quality of water required for the production of a safe, wholesome, and palatable product?

With the exception of blanching and cooking, the use of the renovated wastewater as a process water supply did not adversely affect final product safety or quality. In the blanching and cooking trials the product processed

with the steam produced from the reclaimed water on a batch basis was significantly different than the product processed on a continuous basis with house steam. The fruit processed in the reclaimed water steam was also less palatable due to excessive carmelization. However, these differences were concluded to be the result of inadequate process control during the batch experiments and not the result of using renovated wastewater. Resolution of this issue will require further testing.

Conclusions

In considering the widespread application of technology based on these conclusions, it must be remembered that they specifically relate to treatment and reclamation of a fruit processing wastewater with no sanitary wastes and to reuse in the processing of high-acid (fruit) products preserved in hermetically sealed containers by heat treatment. These conclusions may not apply to low-acid canned foods or frozen fruits and vegetables. Separate investigations must be conducted on these commodities prior to widespread utilization of wastewater reclamation/reuse systems by these industrial segments.

The specific conclusions of this study, which are itemized below, are those of the authors. The final report reuse conclusions will have been cleared by FDA, USDA, EPA and NFPA.

1. Snokist Growers' biologically treated wastewater can be economically polished by filtration and disinfected by chlorination to a quality suitable for reuse within their cannery, except during periods of high suspended solids discharge from the biological treatment system.

2. The lack of consistency and the potential for equipment malfunctions requires that continuous monitoring of reclaimed water quality be sufficient to provide cannery operating personnel with early warning of deterioration. Residual chlorine monitoring at two points, turbidity monitoring of the reclaimed effluent, as well as low chlorine residual and high turbidity alarms at strategic locations in the cannery are necessary to allow the conversion to an alternate water supply for key cannery processes in the event of effluent quality deterioration.

3. Neither the quality nor the safety of the final product was adversely affected by the use of reclaimed processing waste water. Specific uses evaluated were equipment cleaning in the initial processing area, raw product conveying, container cooling, and boiler feed for steam generation. Steam generated from the reclaimed water was used for equipment cleaning in the initial processing area, exhausting, cooking, and blanching. Monitoring for volatile organics in the steam and product was not conducted so reclaimed water steam use for exhausting, cooking, and blanching cannot be concluded as acceptable.

4. Toxic constituents tested for were not present in the reclaimed effluent in concentrations sufficient to cause public health concern for the final products. Heavy metals were at or below primary drinking water standard maximum permissable concentrations. Pesticides were undetectable or below primary drinking water standard levels. Halogenated organics were below proposed drinking water standards. No buildup of these toxicants in the system with extended reuse was apparent, although added testing would be desirable to confirm these results.

5. The reclaimed wastewater was suitable for full scale continuous use for initial raw product conveying, washdown of equipment in the initial processing area of the cannery, floor and gutter washdown, and direct container cooling when the quality is maintained equal to:

   Suspended solids - <30 mg/l,
   Turbidity - <20 NTU,
   Total coliform - <1 organism/100 ml,
   Total plate count - <1000/100ml.

6. The reclaimed effluent was suitable for continuous full scale boiler feed, but when the suspended solids were higher in the reclaimed effluent than in the house tap water, it was less desirable for this use because of potential solids buildup in the ion exchange boiler feed water treatment system. Use of such steam may be restricted to areas where it will not directly contact the product due to the current unknown nature and extent of volatile organics in the steam.

Recommendations

The specific recommendations listed below are those of the authors'; whereas, the final report recommendations will have been cleared through FDA, USDA, EPA and NFPA.

1. Further testing is required to demonstrate consistent performance of the reclamation system. During this demonstration the renovated water should be used for gutter wash on a continuous basis.

2. Once consistent performance has been demonstrated, Snokist should utilize the reclaimed wastewater on a continuous full scale basis for can cooling, initial product conveying, and equipment and floor cleaning.

3. Monitoring of the reclaimed effluent during the demonstration and utilization seasons should include: coliform, fecal coliform, and total plate count analyses to demonstrate sanitary quality; suspended solids and turbidity to demonstrate aesthetic quality; heavy metals, pesticides, polychlorinated biphenyls (PCBs) and halogenated organics to demonstrate whether there is a buildup of toxic or carcinogenic substances during prolonged reuse. The methodology, detection limits, frequency, and quality assurance program for all of these tests should be reviewed by concerned regulatory agencies.

4. Reclaimed water quality criteria for reuse of renovated fruit processing wastewater in critical areas such as direct contact container cooling should be set at:

Coliform	Conform to Interim Primary Drinking Water Standards
Total Plate Count	Equal to or less than 500/ml average, equal to or less than 1000/ml max.
Turbidity	Equal to or less than 20 NTU

Suspended Solids	Equal to or less than 30 mg/l
Chlorine Residual	Measurable residual at the point of use.

5. At Snokist it will be necessary to chlorinate to a residual of approximately 3 mg/l with one hour of contact time to achieve adequate bacterial kill. An alarm system for low chlorine residual and for high turbidity in the reclaimed water should be extended to appropriate plant locations. In the event of a chlorine residual or turbidity alarm during processing, water supply to critical areas such as direct contact container cooling should be converted to house water until the problem is corrected.

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